MUCOOL
Overview & Plans

Overview & Plans	S. Geer	30 mins
RF R&D	R. Rimmer	30 mins
Absorber R&D	M.-A. Cummings	15 mins
Low energy muon cooling	A. Caldwell	10 mins
Related Topic: International Cooling Experiment	D. Kaplan	20 mins

Ionization Cooling

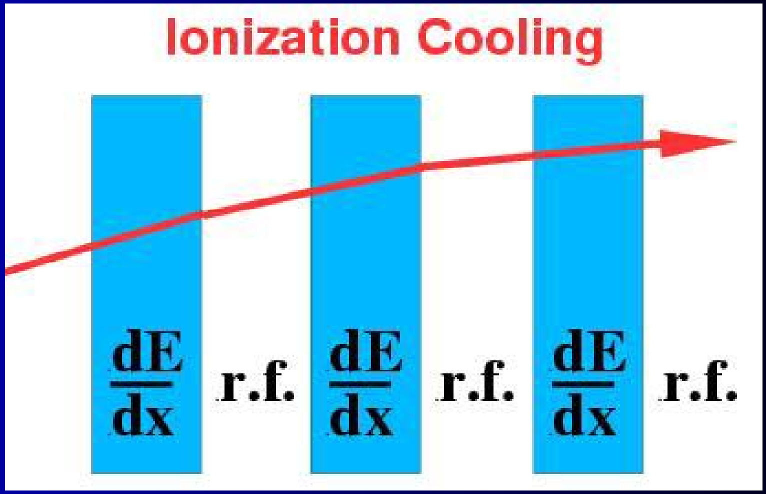
Transverse phase space too large to fit within normal accelerator

Must "cool" the beam fast – Before muons decay

Electron cooling & stochastic Cooling too slow
>> USE IONIZATION COOLING

An ionization cooling channel Can be thought of as a LINAC Filled with material

Need high gradient RF to keep the muons captured



Coulomb scattering tries to heat beam

Use Liquid Hydrogen absorbers

Use strong radial focusing
>> high field solenoid channel

MUCOOL MISSION

Design, prototype, & bench-test all cooling channel components & eventually beam-test a cooling section

Design:	Pursued within the framework of Studies I & II → Simulation + engineering studies
Component R&D:	Activities to develop the required RF Cavities, liquid hydrogen absorbers, & beam diagnositics.
Beam experiments:	Linac area facility for engineering tests International cooling experiment → Dans Talk.

MUCOOL Institutions

16 Institutions from US, Europe, and Japan

RF Development
- FNAL
- IIT
- LBNL
- NWU
- Univ. Mississippi

Beam Diagnostics
- ANL
- FNAL
- IIT
- NIU
- Univ. Chicago

Absorber R&D
- FNAL
- IIT
- KEK
- NIU
- UIUC
- Univ. Mississippi
- Univ. Osaka
- Univ. Oxford

Solenoids
- LBNL

Cooling Experiment
- ANL
- BNL
- FNAL
- IIT
- LBNL
- Princeton
- UCLA
- UIUC
- Univ. Mississippi
- Univ. Indiana

MUCOOL Organization

http://www.fnal.gov/projects/muon_collider/cool/cool.html

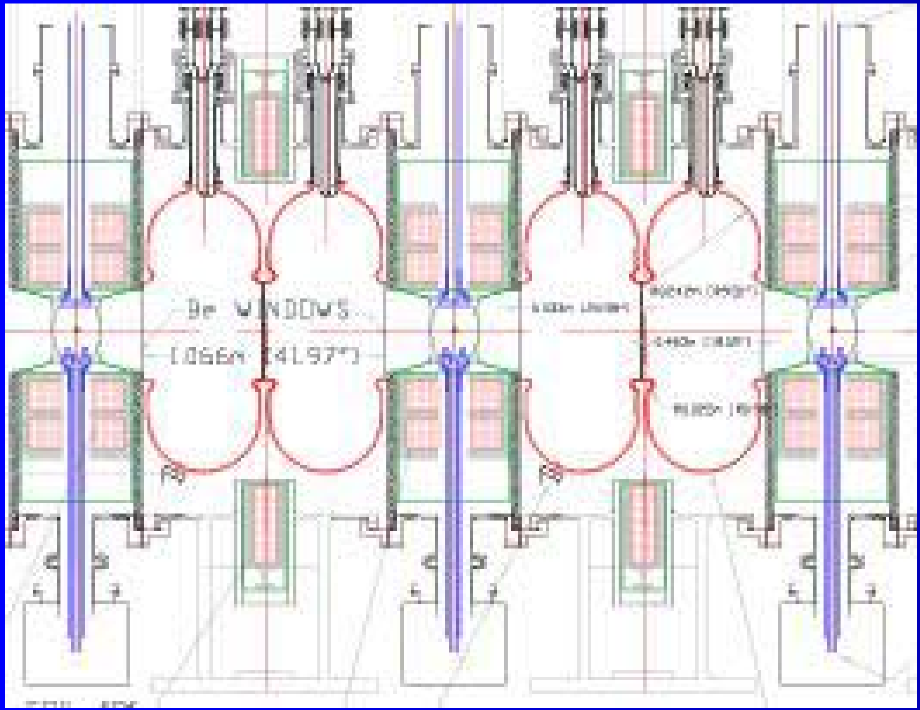
Spokesman:	Steve Geer
BNL Contact:	Rick Fernow
LBNL Contact:	Bob Rimmer

R&D Co-ordinators

RF:	R. Rimmer
	A. Moretti
Absorber	D. Kaplan
Instrumentation Tests:	N. Solomey
Linac Test Area	M. Popovic

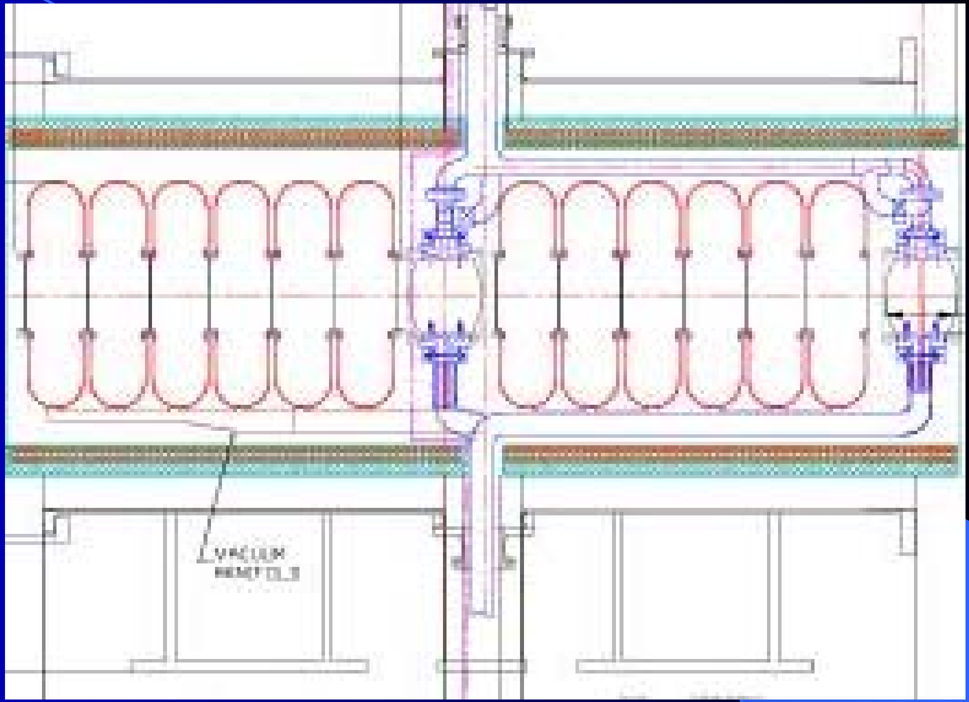
Our Cooling Channel Design

SFOFO Lattice 2: 3.3 m long section



Liq. H RF Liq. H RF Liq. H

DFLIP Lattice: 4.8 m long section

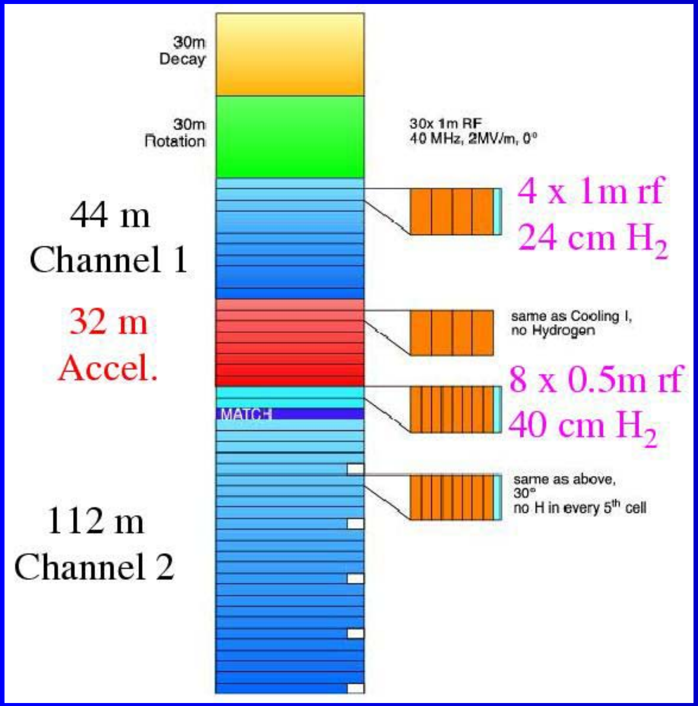


RF Liq. H RF Liq. H

Lattice period: 5.4 m → 3.3 m
High field solenoid : 3T → 5T
Solenoid radius: 33 cm → 20 cm
RF: 17 MV/m @ 201 MHz

Lattice period: 2.42 m → 2.51 m
High field solenoid : 3T → 7T
Solenoid radius: 81 cm
RF: 15 MV/m @ 201 MHz

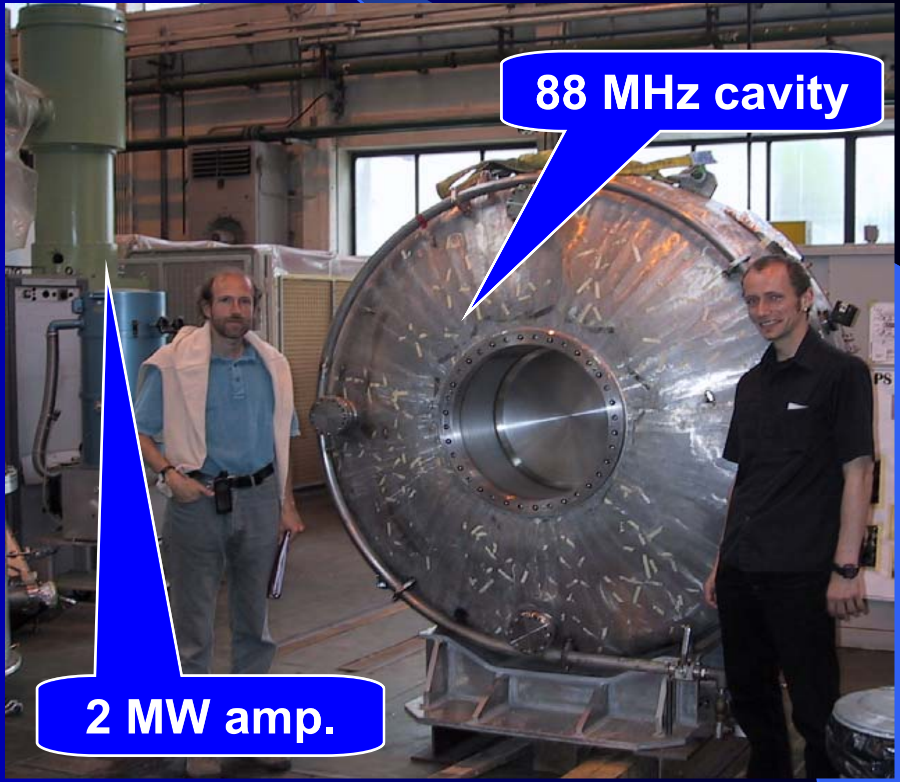
CERN Cooling Channel Design



No Induction Linac – use drift + 44 MHz cavities for the phase rotation

Cooling channel based on 44 MHz & 88 MHz cavities with some acceleration in middle

	Channel 1	Channel 2
Length	46 m	112 m
Diameter	60 cm	30 cm
Solenoid B	2.0 T	2.6 T
RF Freq.	44 Mhz	88 Mhz
RF Gradient	2 MV/m	4 MV/m
Beam Energy	200 MeV	300 MeV



88 MHz High Power test at CERN next year

Choosing the Best Design

We know the SFOFO and DFLIP designs work on paper

Must develop & test the RF Cavities & absorbers to judge how well the SFOFO & DFLIP channels work in practice

CERN channel design studies less detailed than the US studies, So we are now collaborating to help bring the 44/88 MHz based design to the point where its performance can be judged

If a 44/88 MHz based channel also looks promising, we would plan to develop absorbers for this channel, whilst our CERN colleagues develop and test the cavities. This will take a couple of years … at which point we can judge which is the most cost effective design

Cooling Channel Components

201 MHz RF Cavities → 15-17 MV/m

Liquid Hydrogen Absorbers

3T – 7T Superconducting Solenoids

Beam Diagnostics

RF R&D Issues

Issues to do with Feasibility

1. Can we achieve gradients of 15-17 MV/m within solenoid fields of a few Tesla ?
2. Can the dark current exiting the cavity be kept to a level that permits operation of absorbers and beam diagnostics ?
3. Can the windows/grids etc be made sufficiently thin to avoid significant performance degradation due to scattering ?

Issues to do with Cost

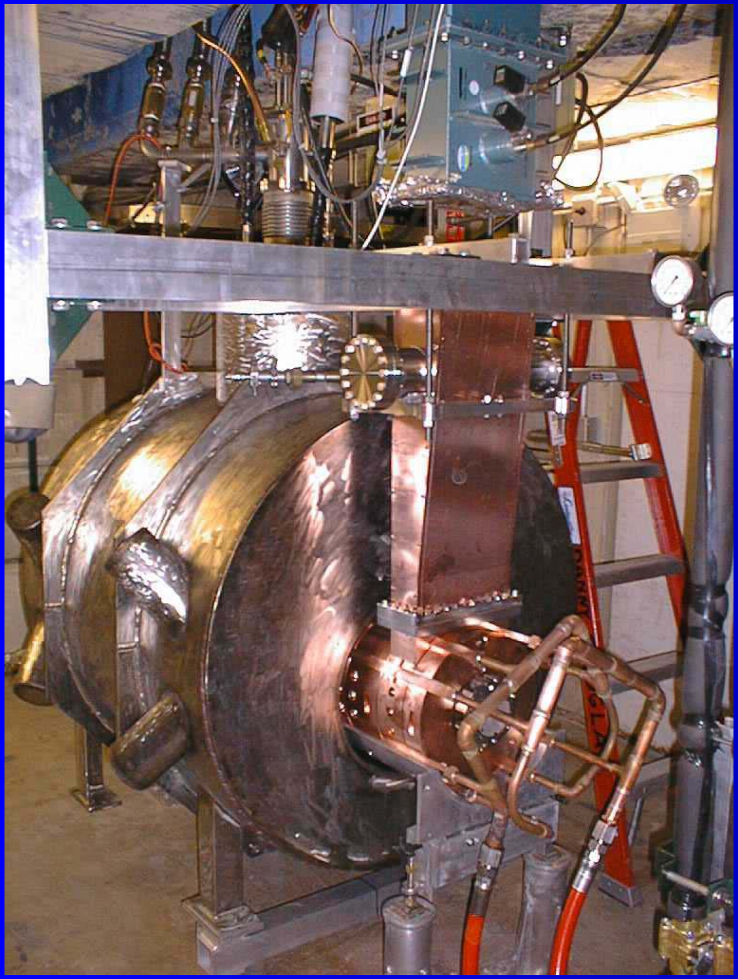
1. Can a more cost effective RF power source be developed ?

RF R&D Institutions

805 MHz Open Cell Cavity	FNAL
805 MHz Pillbox Cavity	LBNL, U. Mississippi
805 MHz Lab G Test Facility	FNAL
Lab G 5T Magnet	LBNL
805 MHz Test Cavity: Breakdown Studies *)	ANL, FNAL
201 MHz Cavity Design	FNAL, IIT, LBNL
Breakdown Simulations*)	NWU
Dark Current & X-Ray Studies	ANL, FNAL, IIT, Princeton, UIUC

*) Planned

RF R&D at Lab G: Overview



805 MHz open cell cavity in 5T solenoid at Lab G

After 2.5 years of preparation we have an 805 MHz high power test facility at Lab G which we are using to confront the R&D issues related to cavity operation in multi-Tesla magnetic fields.

12 MW klystron
Linac-type modulator & controls
X-Ray cavern
5T two-coil SC Solenoid
Dark-current & X-Ray instrumentation

Became operational : May 2001

Multi-cell cavity operated at full power:
Peak surface gradient: 53 MV/m,
Peak accel. Gradient on-axis: 23.5 MV/m

Observe large dark currents & cavity operation
Changed by magnetic field → R. Rimmer Talk

RF R&D Accomplishments & Plan

High Power Be Foil Tests at A0	DONE
Prototype Be Windows for 805 MHz Cavity	DONE
805 MHz Pillbox Cavity Design	DONE
Low Power Cu Pillbox Cavity with Be Windows	DONE
High Power Cu Pillbox Cavity with Be End Plates	BUILT; Test FY02
Open Cell 805 MHz Multi-Cell Low Power Cavity	DONE
Open Cell 805 MHz Multi-Cell High Power Cavity	DONE
5T SC Magnet for Lab G	DONE
Lab G 805 MHz High Power Test Facility	DONE
Open Cell 805 MHz Conditioning (B=0T)	DONE
Open Cell 805 MHz High-Power studies (B>2T)	Ongoing
High Power Studies: Pillbox Cavity	FY02
New single cell cavity for breakdown studies	Being planned

RF R&D Accomplishments & Plan

201 MHz Cavity Foil & Grid Tests	FY02
201 MHz Cavity Design	FY02
201 MHz Cavity Construction	FY03 *)
201 MHz High Power Tests	FY04 +)
SC Solenoid for 201 MHz Cavity: Design	FY02 *)
SC Solenoid for 201 MHz Cavity: Construction	FY04*)
201 MHz Cavity Test in Solenoid, with p-beam	FY04/5 +)

*) Schedule resource limited

+) Assumes latest guidelines (15 Oct) for Fermilab FY02 support for LINAC Area, assumes continued support FY03/4

Absorber R&D Issues

Can liquid hydrogen absorbers be built so that they satisfy all safety issues, and :

i) A few x 100 W of dE/dx heating is removed

ii) The windows are sufficiently thin to avoid performance degradation due to scattering

iii) Absorbers are compact, and fit within the confines of a cooling channel

Absorber R&D Institutions

Window design & development	IIT, NIU, UIUC, FNAL, U. Mississippi, U. Oxford
Window test facility	NIU
Absorber filling & beam test facility	FNAL
Forced Flow Absorber	IIT, U. Mississippi
Convection Driven Absorber	IIT, KEK, U. Osaka
Absorber beam tests	FNAL, IIT, NIU, UIUC, U. Mississippi, KEK, U. Osaka

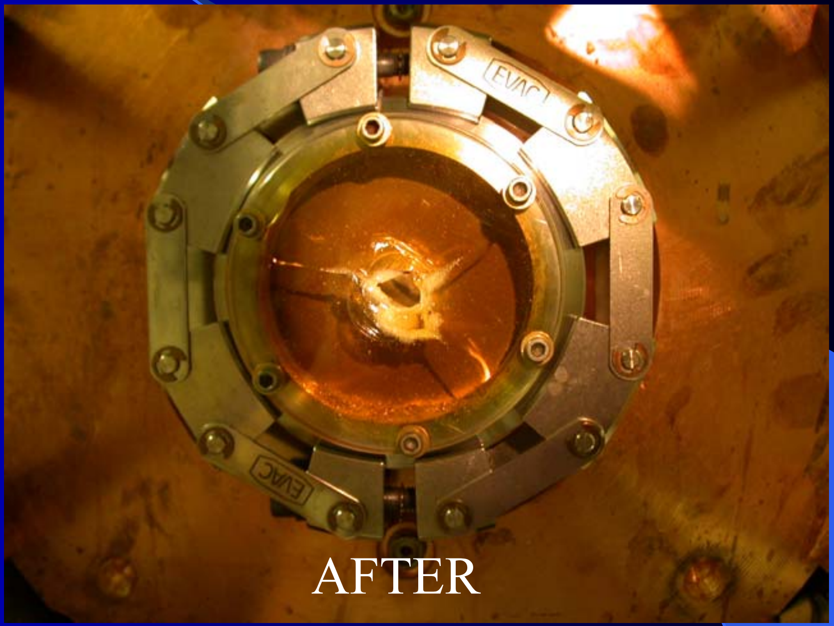
Absorber R&D Accomplishments + Plan

Forced flow absorber conceptual design	DONE
Convection driven absorber conceptual design	DONE
125 µm window manufacture & profile verification	DONE
125 µm window pressure & rupture test	DONE
330 µm window manufacture & profile verification	DONE
330 µm window pressure & rupture test	DONE
330 µm window pressure & rupture test (repeat 4 times)	FY02
Forced flow absorber flow test	FY02
Convection driven absorber flow test	FY02
Absorber filling station preparation +)	FY02/3
First absorber filled +)	FY03
Absorber Linac area beam tests in 5T magnet +)	FY04

+) Assumes latest guidelines (15 Oct) for Fermilab FY02 support for LINAC Area, assumes continued support FY03/4

Instrumentation R&D

Must understand the environment near to a cavity operating within a solenoid
As a demonstration, ¼ inch plexiglass windows melt unless cooled :



Measuring (& reducing) the dark current from the cavity is part of our RF R&D program.

The final X-Ray & dark current levels we achieve will determine the type of Instrumentation that can be used for beam diagnostics, and cooling required.

Instrumentation R&D & Institutions

University groups within MUCOOL have been interested in developing particle detectors for a muon cooling experiment, and in possible beam diagnostics for a cooling channel → hardware activities at:

ANL, FNAL, IIT, NIU, U. Chicago, UCLA, U. Mississippi, Princeton

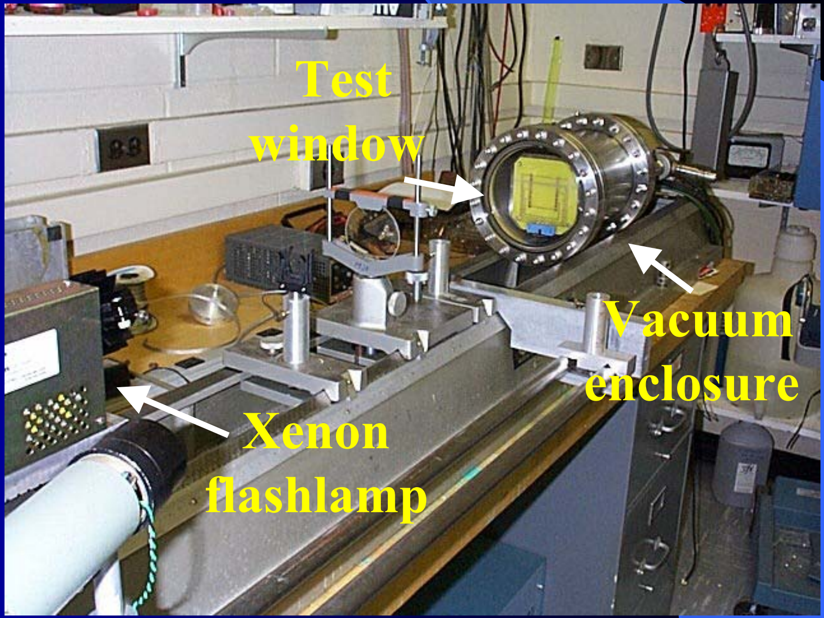
We have very limited resources to devote to instrumentation R&D at present, but have been able to make some with two promising ideas:

- Fast timing R&D: FNAL, NIU, UCLA

Built & operated first timing head
Preliminary risetime jitter measured to be < 25ps
Cryo-system for superconducting TDC set up

- Beam Profile Bolometer : Univ. Chicago

Test setup built
Proof-of-Principle device made & tested



MUCOOL Linac Test Area - 1

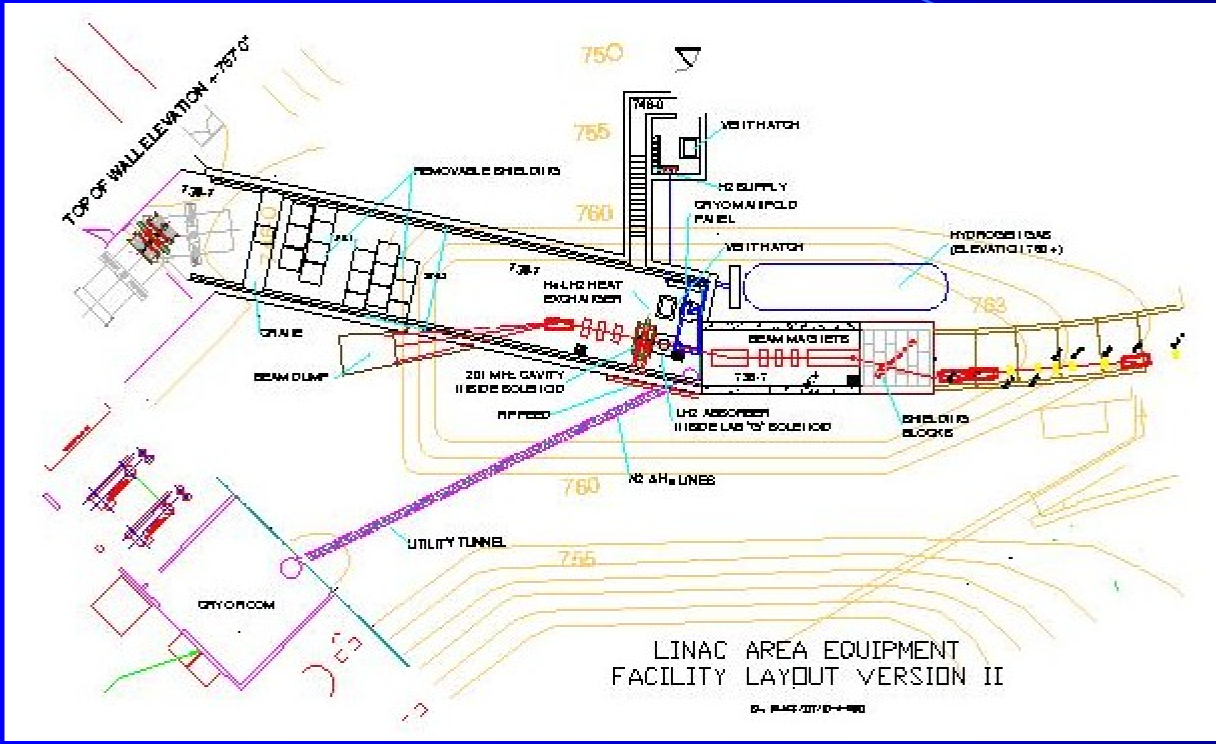
Goal: Provide a test area for MUCOOL in which we can:

i) Fill prototype liquid hydrogen absorbers, and expose them to a beam depositing an appropriate energy to fake dE/dx losses in a cooling channel, and with an appropriate beam spot size. Tests will be made within a 5T solenoid (moved from Lab G).

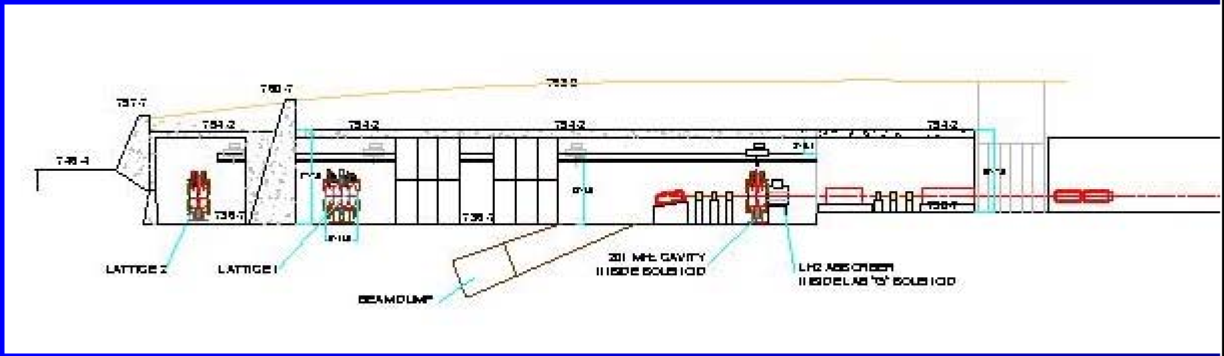
ii) Test a 201 MHz cavity under high-power, within a ~3T solenoid, exposed to a beam.

MUCOOL Linac Test Area - 2

MUCOOL Linac Test Area - 3



Assuming 15 Oct guidelines for Fermilab FY02 support we would be able to complete civil construction in FY02. Assuming continued support in FY03/4 at FY02 level, beamline preparation could be accomplished in FY03/4, and operation in FY04.



We have just been given new information about the FY02 funding, and the context in which many things will be evaluated for FY03 support at Fermilab. The Collaboration will need to absorb this information & re-optimize its plans.

International Cooling Experiment

For some time we have wanted to design & propose a muon cooling experiment. This is also true of our European & Japanese colleagues … but it will be a large scale endeavor and no one region seems to have the resources to do it alone.

The experiment will be proposed within an International framework, and will require new funds to mount.

The present idea is that MUCOOL will provide absorbers & perhaps RF cavities … which is consistent with our component development program … and some of the instrumentation … consistent with our historical interests and investment.

Different proponents want the experiment for different reasons. I believe it will :

i) Validate our simulations of muons propagating through a periodic lattice within a solenoid channel with RF and absorbers.

ii) Build an International framework within which we can make the right cooling channel design choices in a few years time.

Summary

1. The MUCOOL Collaboration is pursuing cooling channel design and component development.

2. Resources are limited, so the primary focus is on RF & absorber development.

3. Hardware highlights this year have been bringing Lab G into operation, coming into contact with the dark current issues, pushing forward an attractive plan for the next generation MUCOOL test facility (at the FNAL Linac) and successfully making and testing absorber windows.

4. We have a good plan for FY02-04 … it is evolving to respond to evolving budget constraints.